UPDATE ON THE USE CASE FOR THE TRANSMISSION BUS LOAD MODEL (TBLM)
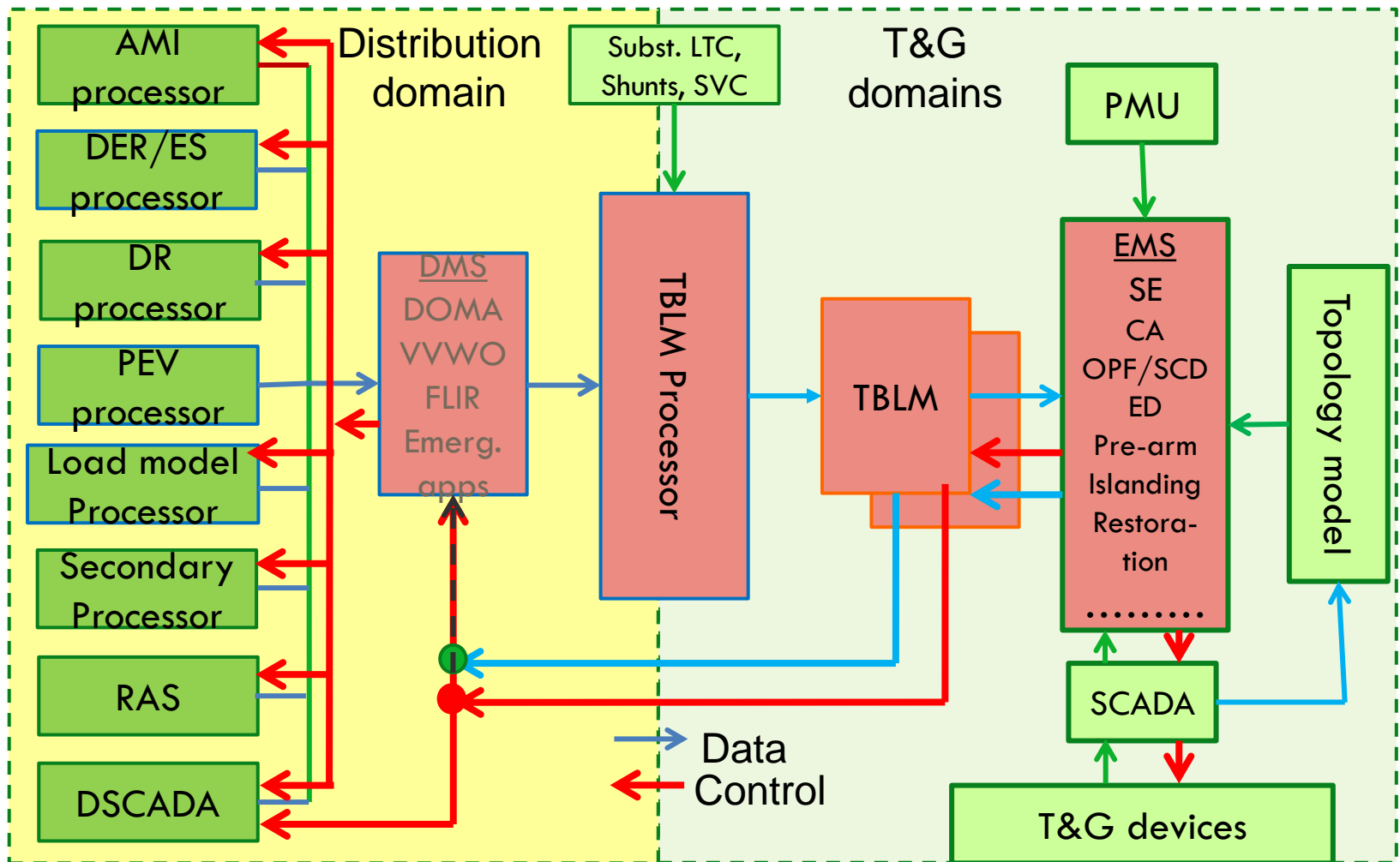
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SGiP SMART GRID INTEROPERABILITY PANEL

Information Exchange between T&D Domains

Scenarios for TBLM Use Cases

1. Develop aggregated DER capability curves for TBLM
2. Develop aggregated model of dispatchable load for TBLM
3. Develop aggregated real and reactive load-to-voltage dependencies
4. Develop aggregated real and reactive load-to-frequency dependencies
5. Develop aggregated real and reactive load dependencies on Demand response control signals
6. Develop aggregated real and reactive load dependencies on dynamic prices
7. Adapt aggregated real and reactive load models to current weather conditions
8. Develop aggregated real and reactive load dependencies on ambient conditions and time for the short-term forecast of the aggregated load
9. Develop models of overlaps of different load management functions, which use the same load under different conditions.
10. **Assess the degree of uncertainty of TBLM component models.**

Components of TBLM uncertainty

Uncertainty of load models

- **Uncertainty of base nodal loads in distribution**

- **Uncertainty of forecast of external factors (weather, price, etc.)**

- **Uncertainty of load dependencies on external factors (weather, price, etc.)**

- **Uncertainty of load-to-voltage dependencies**

- **Uncertainty of load-to-frequency dependencies**

- **Uncertainty of overlapping load components**

Uncertainty of DER models

- **Not monitored DER**
    - **Participation**
    - **Mode of operations and settings**

- **Monitored DER**
    - **Uncertainty of effective capability curves**
    - **Assessment of look-ahead performance based on expected external input and power flow model**

- **Intermittent operations**

Other uncertainties

- **Uncertainty of secondary equivalent models**
- **Uncertainty of DR models and behavior**
- **Uncertainty of execution of commands and requests**
  - **Uncertainties of control actions (e.g., the bandwidth of voltage controllers)**
  - **Uncertainties of utilization of dispatchable load**
- **Errors of measurements (e.g., the measurements of reference voltage and other used for state estimation)**
- **Errors of modeling (e.g., power flow models)**
- **Other**

Example of a DER capability curve vs bus voltage
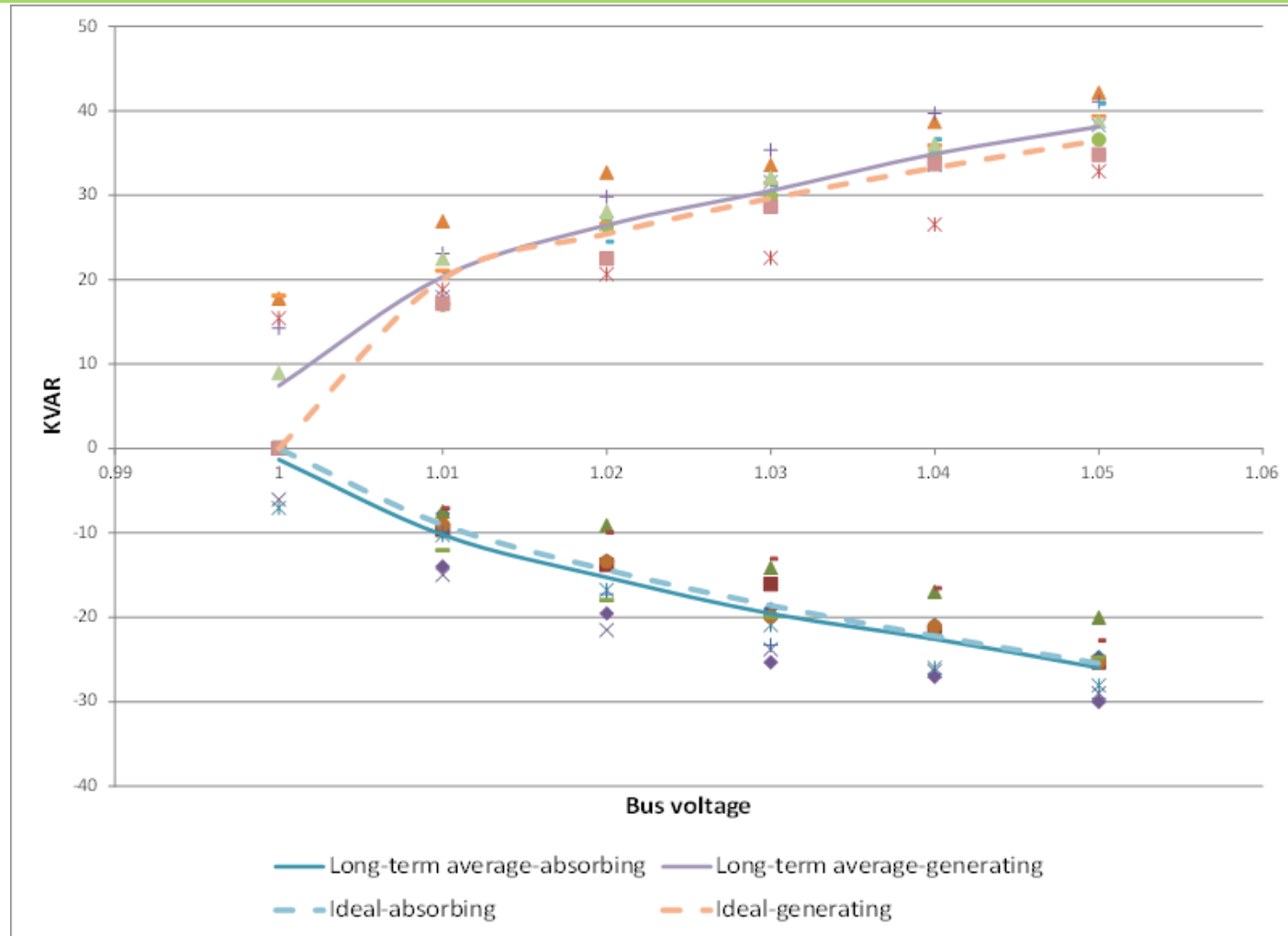
Uncertainties depend on the use of TBLM

- The uncertainties of the components of the TBLM are different for a particular instance of the model utilization and for a series of utilizations.

- The uncertainty of the average impact of the series of TBLM utilization is typically smaller than the uncertainty of an individual instance due to the random components and low correlation of the errors.

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Information support for assessing the uncertainties of TBLM

- Some components of uncertainty can be assessed analytically.

- In other cases, the uncertainties can be derived statistically based on samples of comparison between the models and the measurements.

    - These statistics can be clustered differently for different conditions. For instance, the statistics of DER model uncertainties during clear sky days would be different from the ones for the cloudy days.

- Hence, collections of measurements from representative primary sources will be needed for the validation of the models, including the assessment of the model errors.

Uncertainty of load models

Uncertainty of short-term forecast of aggregated load

- The **real-time values of the bus load** are measured (typically by SCADA), and the uncertainty of these values are defined by the accuracy of the measurements.

- The **short-term forecasted load** values are used by EMS decision-making applications as initial load before the effects of the to-be-implemented solutions take place in the short-term look-ahead time intervals.

- The **changes of the loads during and after the solutions are implemented** are also subjects of the TBLM and have a degree of uncertainty.

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The components of the load aggregated at the T/D bus

- Customers' natural (nominal) load

- DER generation/absorption

- Implemented Demand Response

- Other reactive power sources generation/absorption

- Power losses

- Load changes due to voltage deviations

- Load changes due to weather and other external conditions

Illustration of a short-term forecast of the aggregated reactive load (DER penetration is 20%).
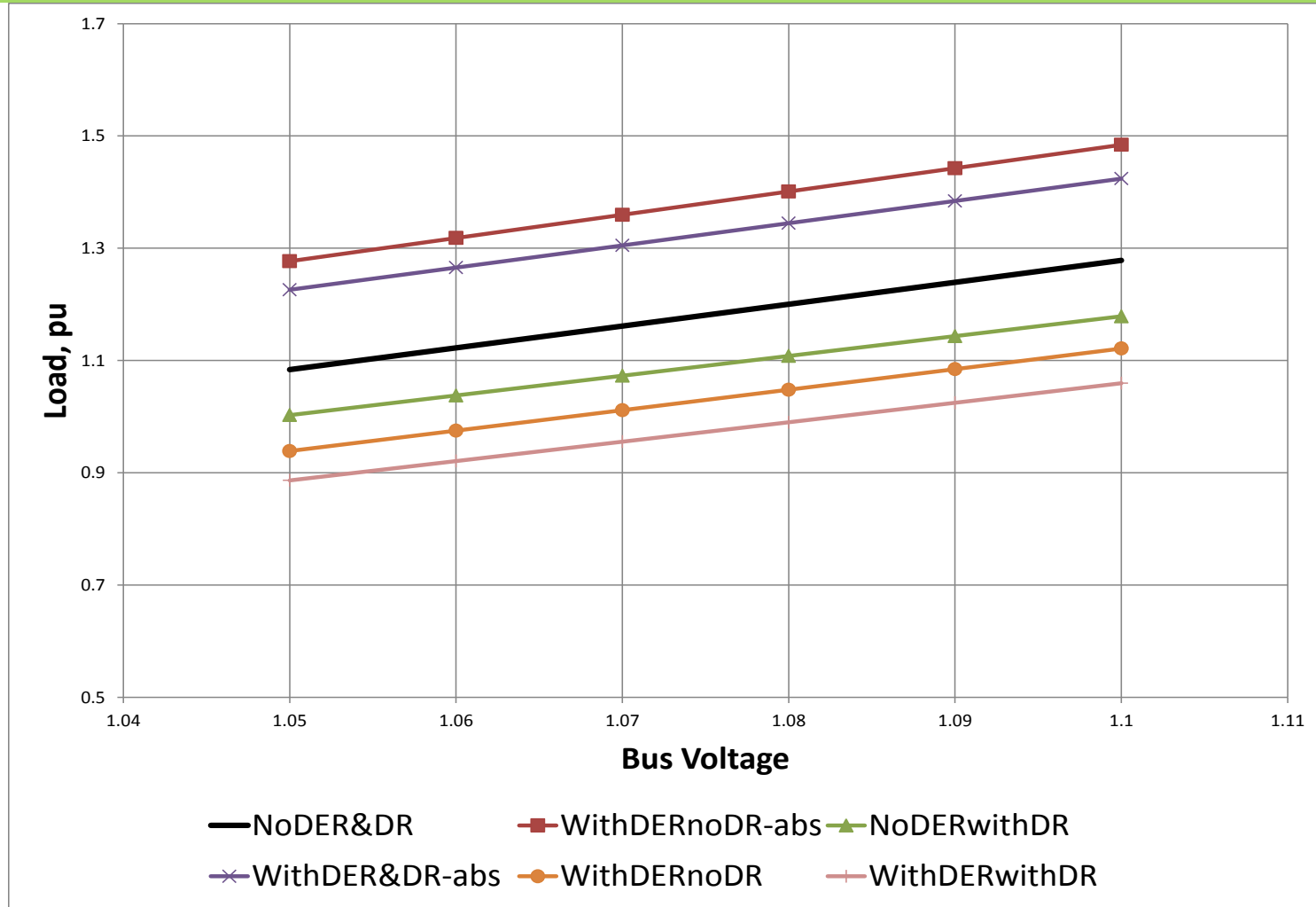
Knowledge of the states of DER and DR is critical

- If the participation of the DER and DR components is unknown, the TBLM uncertainty may range within ±20%.

- The basic (nominal) primary information about DER should include the following:
  - The DER capability curves (tables)
  - The modes of operations and the settings of the DER under steady-state, intermittent, and abnormal operating conditions
  - The rules of changing the modes of operations and settings
  - The near real-time measurements from large DER systems
  - Other

Knowledge of the states of DER and DR is critical (cont.)

- The nominal information about the DR should include the contractual conditions for individual or clustered DR systems.

- Analyses of historic data on the **responsiveness of the DER and DR systems to different kind of triggers** should be performed and used for the assessment of the DER performance under different modes of operations and external conditions.

  - Note : The degree of uncertainty caused by the same factor can be different under different conditions and times (sunny/cloudy, peak / off-peak…)

Causes of uncertainties of the load models due to the execution of the applications

- Uncertainties of load models associated with load management means

- Uncertainties of models of overlapping loads between load management means

- Uncertainties of load dependencies on voltage and frequency

- Uncertainties of the performance of DMS applications

  - Note: What is insignificant under normal conditions may become significant under contingencies.

- Many of these uncertainties are of random nature with low correlation

Impact of systemic errors

- Errors of some component models under some conditions cannot be considered random errors.

- Information about the probable systemic error should be available to the relevant DMS and EMS applications.

- Examples of causes of systemic errors of the look-ahead model components:

  - Errors in weather forecast
  - Errors in look-ahead price signals
  - Uncertainties of voltage control due to the bandwidths of the controllers …

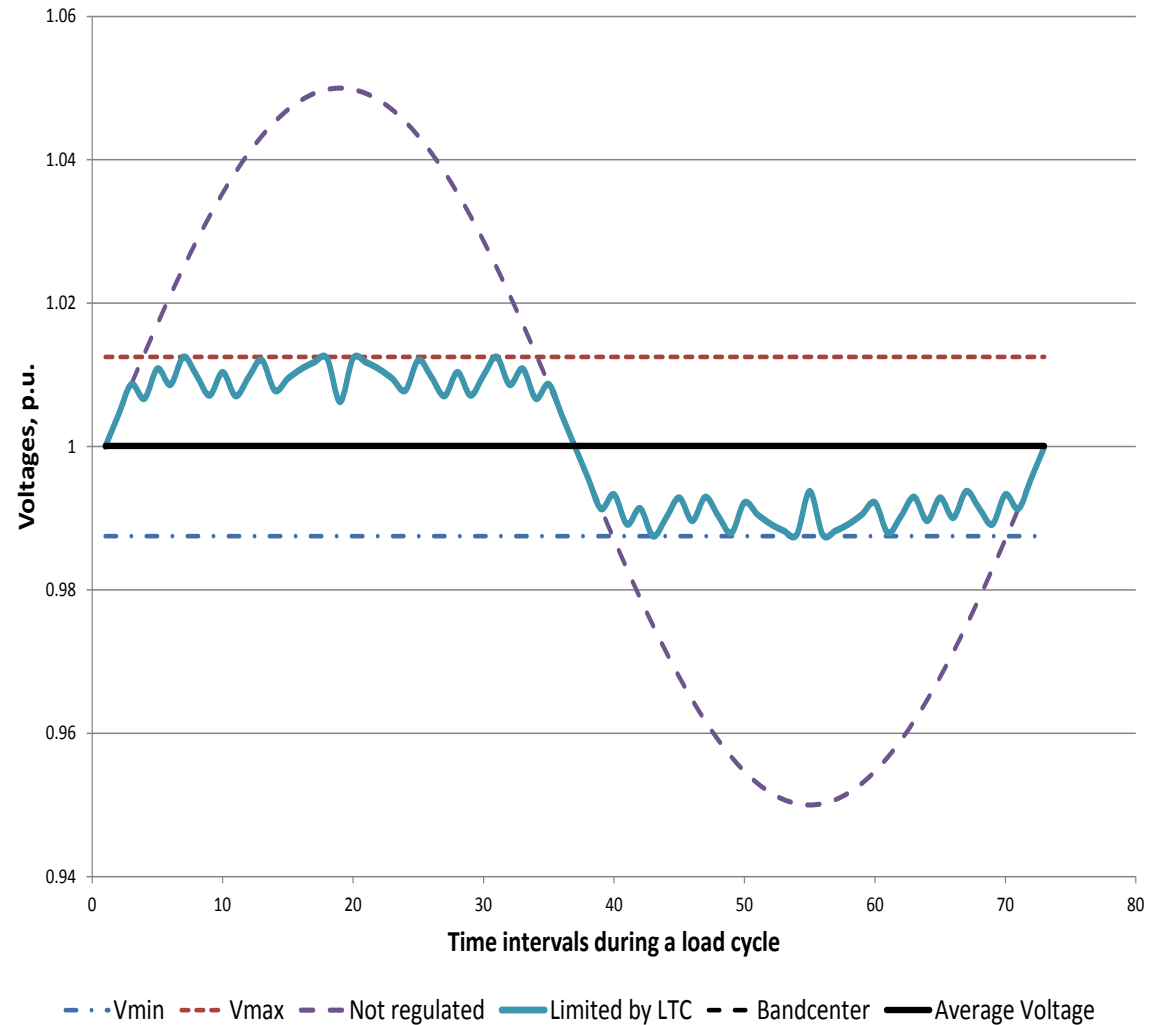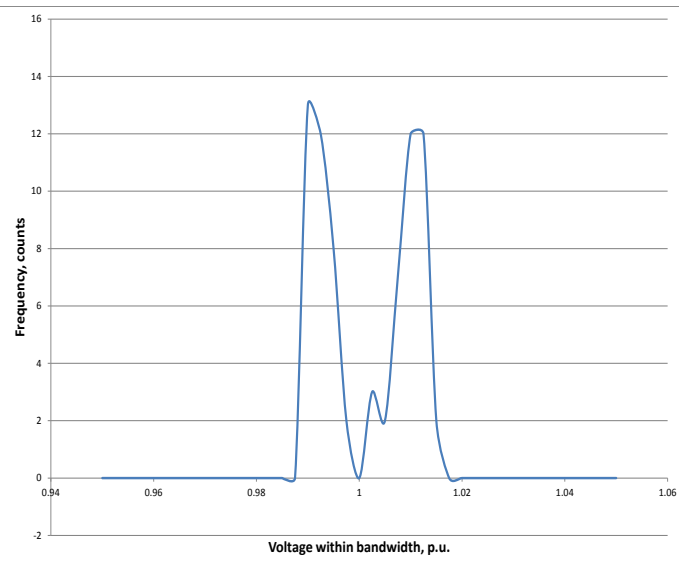# Uncertainty of voltage control (1)

Symmetrical unregulated voltage deviations. Bandwidth = 2*LTC step (0.625%)
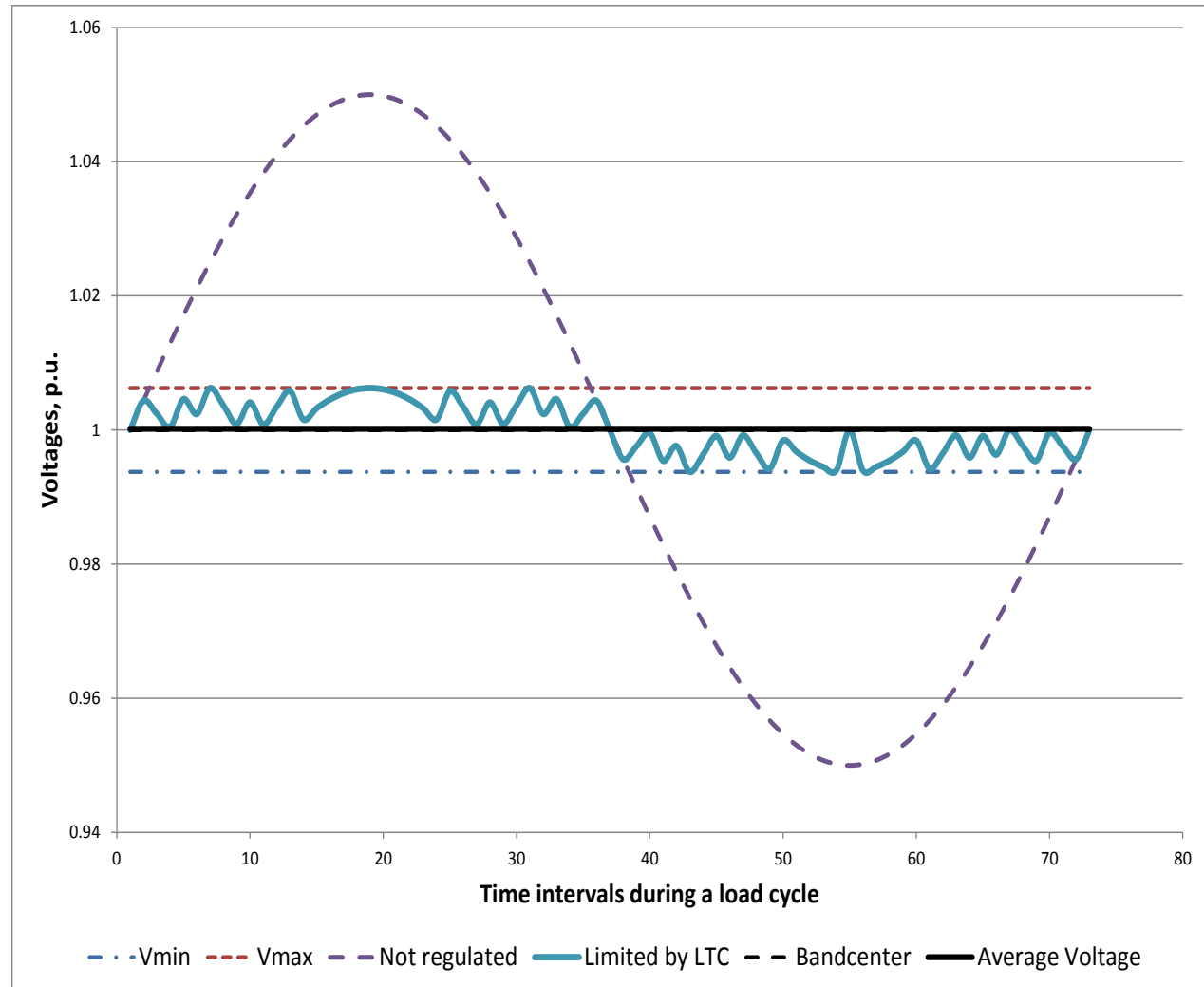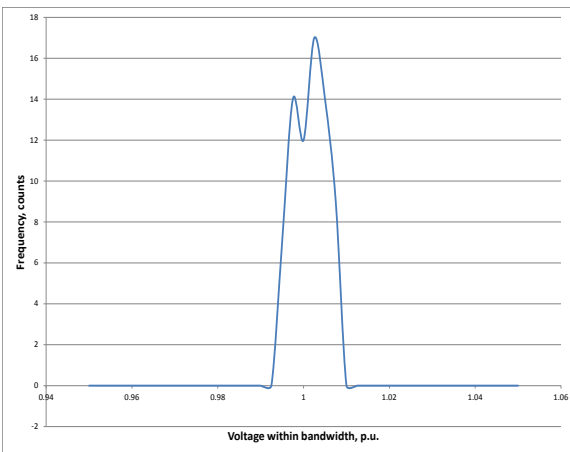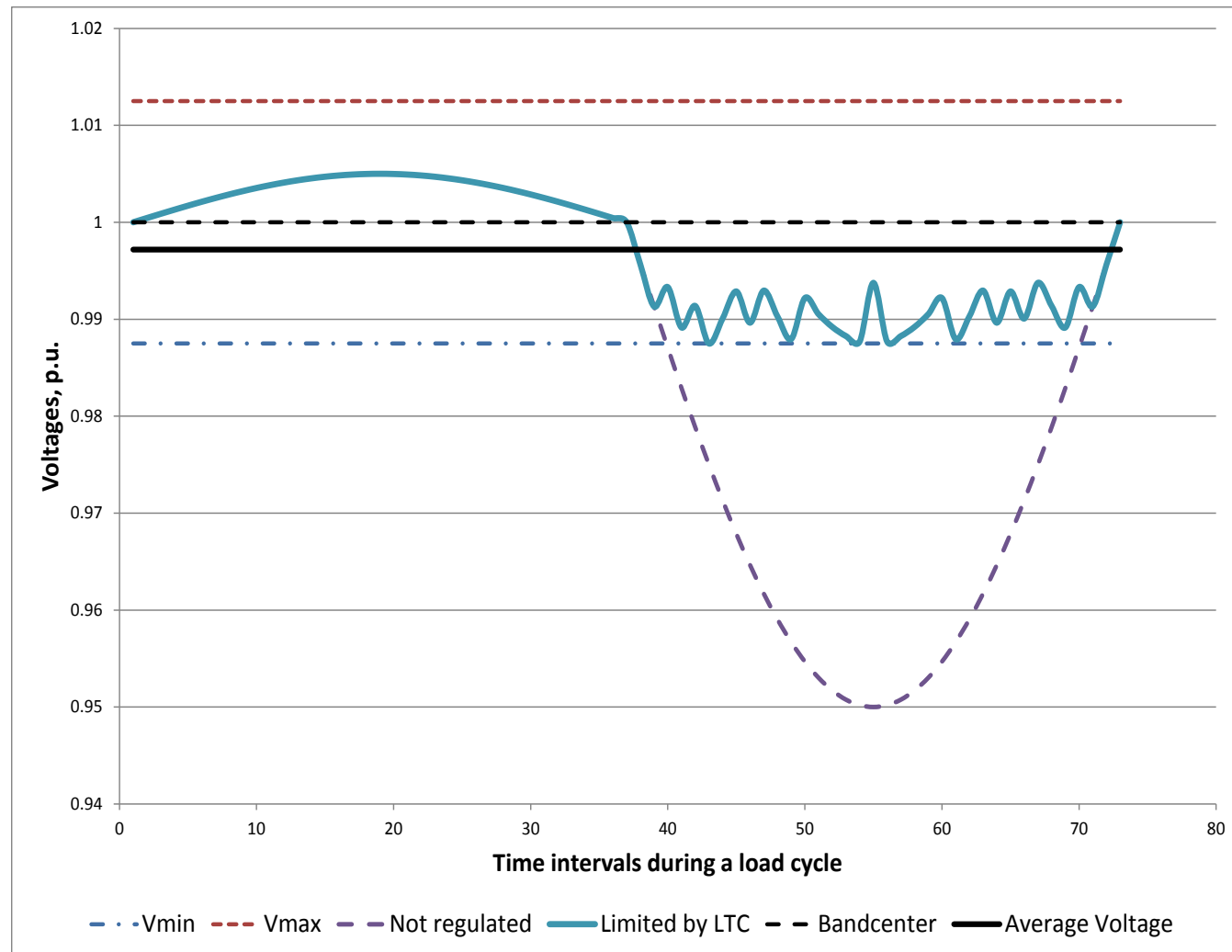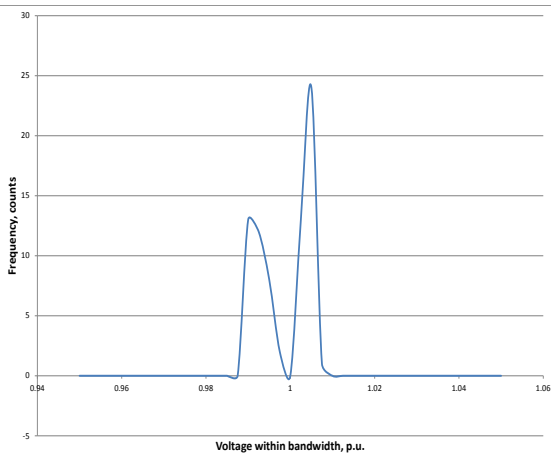
Uncertainty of voltage control (2)

Bandwidth = 4*LTC step
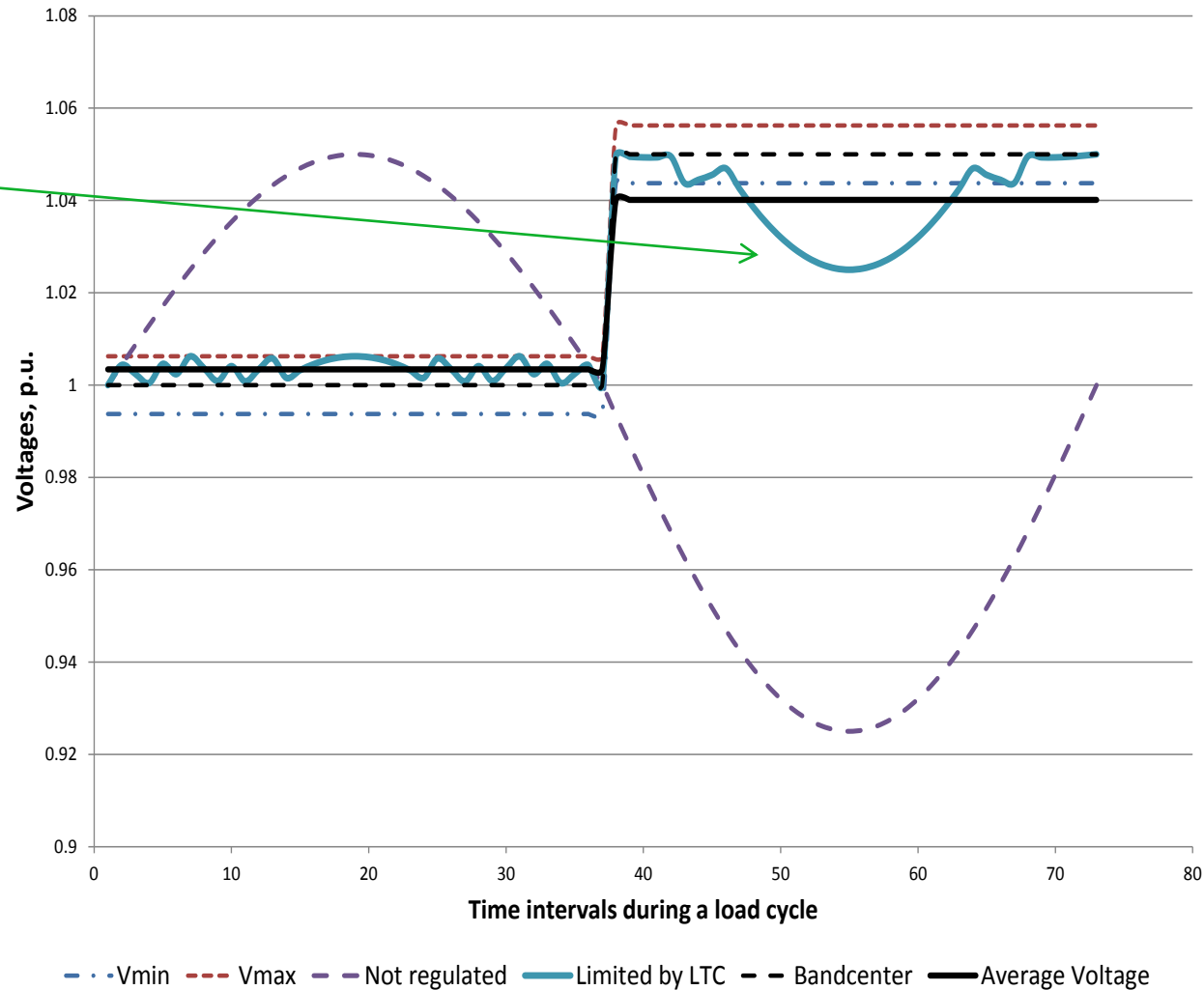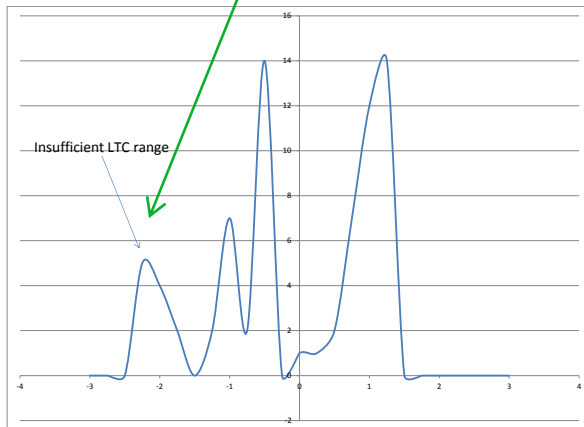(0.625%)

Uncertainty of voltage control (3)

Asymmetrical unregulated voltage deviations. Bandwidth = 4*LTC step (0.625%)

Uncertainty of voltage control (4)

Insufficient regulation range of LTC.

Uncertainty of voltage control (5)

- **As it follows from the above examples, to assess the systemic error in voltage control, the following must be known:**
  - **the size of the steps of control**
  - **the size of the bandwidth**
  - **the current or prospective band-center settings**
  - **the position of the uncontrolled voltage relative to the control settings**
  - **the current availability of range of the controlling devices**

Conclusions.

- The ranges of uncertainties of TBLM components must be known to the DMS and EMS applications to avoid harmful decisions and to realistically assess the expected benefits of the dynamic optimization.

- The lack of the knowledge of the expected nominal states of large individual and clusters of localized DER and DR and of the secondary equivalent contributes most of the TBLM uncertainty.

Conclusions (cont.)

- The information about the reference states of the DER and DR can be made available by using **SCADA, customer-side information resources**, and other data acquisition means, utilizing corresponding interoperability standards, like IEC 61850 (for collecting primary information) and IEC 61968 for exchanges between the various Data Management and Modeling Systems and TBLM-related set of applications.

- The information about the reference nodal loads and secondary equivalents can be made available via **AMI, communication with customer EMS**, and micro-grid controllers and by processing historic data in load and secondary equivalent processors.

Conclusions (cont.)

- The actual states of the component models used for developing the TBLM may differ from the reference states by **random and systemic** errors.

- It can be expected that the composite TBLM errors due to the random errors of the multiple components are not critical because of the mutual compensation of the random and weakly correlated individual errors.

- The uncertainty of the average **impact of series of TBLM utilization is typically smaller** than the uncertainty of an individual instance due to the random components of the errors.

Conclusions (cont.)

- The systemic errors of components may be critical, especially if they are errors of dominant components

- Obtaining such information may require the use of communication means with the field equipment and between the EMS and DMS databases and applications

- Additional Object Models may need to be developed

Thank you!

Questions?